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ORIGINAL PAPER

Navigating Stock Market Turbulence: The Dynamic Effect of Time-Varying Volatility on the Poland WIG 20 Index via an Exogenous EGARCH Approach

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Abstract

This paper investigates how time-varying volatility, market shocks, and exogenous price factors influence return dynamics in the Poland's equity market. Using a comprehensive dataset of 7,642 daily observations of the WIG20 Index spanning from January 1996 through July 2026, we apply a suite of GARCH-family specifications including standard GARCH(1,1), Exogenous GARCH, Exponential GARCH (EGARCH), and Component GARCH (CGARCH) models following preliminary ADF, KPSS, and ARCH-LM diagnostic testing. The empirical findings c onfirm that daily log returns on the WSE exhibit stationary behavior accompanied by strong leptokurtosis and pronounced volatility clustering. Incorporating lagged intraday price dimensions reveals that prior-day open returns positively affect conditional volatility, whereas lagged low returns exert a stabilizing negative influence. The EGARCH variance estimates reveal a statistically significant asymmetric leverage effect ($\boxed{\gamma = -0.0489, p < 0.001}$), confirming that negative shocks generate disproportionately higher market volatility than positive news of equal magnitude. Furthermore, the Component GARCH results demonstrate a clear structural split between transitory variance and a persistent, long-memory permanent trend ($\boxed{\rho = 0.9968}$). These insights offer institutional investors, risk managers, and market regulators a nuanced framework for modeling conditional risk across Eastern European financial markets.

Keywords: WIG20 Index, Volatility Clustering, Exogenous EGARCH, Asymmetric Leverage Effect, Component GARCH, Warsaw Stock Exchange, Conditional Variance

JEL Classification: C32, G10, G12, G17

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Introduction

Understanding risk dynamics in emerging and transition equity markets remains a central challenge in financial economics. The Warsaw Stock Exchange (WSE) serves as a primary financial hub in Central and Eastern Europe, with its benchmark WIG20 Index, comprising twenty of the largest and most liquid listed firmsacting as a crucial barometer for capital flows across the region. Over the past three decades, the Poland's capital market has experienced major structural evolutions, shifting economic policy regimes, and international integration. These transitions make the WIG20 a compelling candidate for long-run volatility modeling.

A foundational assumption in classical finance is that return variances remain constant over time. However, empirical stock returns consistently display non-linear properties, such as fat-tailed error distributions, persistent volatility clustering, and distinct reactions to market shocks. While traditional GARCH structures account for basic autoregressive conditional variance, they struggle to capture direction-dependent reactions (leverage effects) or integrate information from short-term intraday price ranges.

This study examines these dynamics using a 30-year sample of WIG20 daily returns. By deploying an Exogenous EGARCH framework alongside asymmetric and component variance architectures, we isolate the impact of immediate shocks, historical intraday price bounds (Open, High, Low), and long-term structural variance. In doing so, this paper clarifies how information gets processed in the Poland's equity market, offering practical tools for portfolio optimization, derivative pricing, and systemic risk monitoring.

Review of Literature

Numerous empirical research studies analyze the behavior of stock markets, making it an area of high interest and widely debated in the specialized literature. For instance, it is relevant to highlight recent research studies such as the following: Meher et al. (2023), Trivedi et al. (2022), Kumar et al. (2021), Spulbar et al. (2023a), Aman et al. (2024), Anand et al. (2023) and many others. Chirilă conducted an empirical research study on the stock market in Poland before but also during the COVID 19 pandemic considering the linkages between certain economic sectors, but also the dynamics of volatility. Bieszk-Stolorz and Markowicz (2022) analyzed the behavior of Warsaw Stock Exchange in the context of COVID-19 pandemic while being focused on listed companies.

Jareño et al. (2021) have conducted a comparative empirical study on the non-linear linkages as reciprocal relationship of most important indices of the European stock markets in Poland and Spain, but also several other relevant stock markets in Germany, USA, China and UK. Spulbar et al. (2023b) developed a comparative empirical research study on the dynamics of European stock markets in Poland and Italy using GARCH models.

Stereńczak (2020) investigated the impact of stock liquidity for the case of Polish stock market, such as Warsaw Stock Exchange. Będowska-Sójka and Echaust (2019) have conducted an empirical research study based on certain emerging European stock markets such as Hungary, the Czech Republic, Poland, Russia and Turkey considering essential aspects such as liquidity. Moreover, the issue of stock liquidity premium was analyzed in detail based on this applied empirical study considering other key aspects such as stock market volatility, stock returns but also the liquidity volatility. Moreover, Nawrocki and Szwajca (2022) examined the implications of reputation on the dynamics of Polish capital market.

Research Gap

While an extensive body of literature applies standard symmetric GARCH model frameworks to evaluate conditional volatility across developed and emerging stock markets, significant empirical gaps remain regarding the Poland's equity market specifically the WIG20 Index.

First, existing empirical research on Central and Eastern European (CEE) markets predominantly utilizes baseline univariate models that assume symmetric variance responses to market shocks. This creates a critical gap in understanding how directional news asymmetries specifically the leverage effect operate over extended multi-decade periods that span diverse economic regimes, regulatory shifts, and structural market transitions.

Second, conventional ARCH/GARCH modeling approaches routinely treat conditional variance as a closed function of lagged squared residuals and historical variance terms. Few studies incorporate short-term intraday price dynamic ssuch as lagged open, high, and low price returns directly into the conditional variance equation as exogenous predictors. Consequently, there is a lack of empirical evidence regarding how prior-day price bounds act as exogenous news drivers that alter immediate risk behavior in the WIG20 Index.

Third, standard volatility models fail to separate short-run transitory fluctuations from long-run structural trend components. Most existing studies evaluate overall persistence without decomposing whether volatility shocks in the Poland's market exert a permanent structural impact or merely temporary noise.

This study directly addresses these interconnected gaps by applying a comprehensive, multi-model empirical framework combining Exogenous GARCH-X, Exponential GARCH (EGARCH), and Component GARCH (CGARCH) models to a continuous 30-year daily dataset of the WIG20 Index (7,642 observations). By simultaneously evaluating exogenous price signals, leverage asymmetries, and permanent-versus-transitory volatility decomposition, this paper provides a more complete framework for understanding time-varying risk dynamics in Poland's primary stock index.

Scope and Limitations of the Study

1. **Scope of the Study:**

- **Sample Period:** Analyzes 7,642 daily closing observations from January 5, 1996, to July 21, 2026, capturing long-term market trends across different economic cycles.
- **Model Suite:** Evaluates conditional variance dynamics using GARCH(1,1), Exogenous GARCH-X, Exponential GARCH (EGARCH), and Component GARCH (CGARCH) models formulations.
- **Variable Integration:** Combines transformed daily logarithmic return series with lagged intraday price components (opening, high, and low levels).

2. **Limitations of the Study:**

- **Exogenous Inputs:** Exogenous variance predictors are restricted to internal price metrics (Open, High, Low); macroeconomic variables (such as central bank policy rates, inflation indicators, and exchange rate shifts) are excluded from the variance specification.

- **Distributional Assumptions:** Estimation relies primarily on standard normal innovation distributions, which may not fully capture extreme tail risks during severe market distress.
- **Single-Index Focus:** The empirical scope is limited to the composite WIG20 Index, meaning sector-level dynamics and individual asset spillovers within the WSE fall outside the study's framework.

Objective of the study

To examine the effect of lag volatility of WIG20 on today's price.

To quantify the size effect, sign effect and persistence level on the volatility of WIG 20 return.

To analyse existence of short term and long-term components in WIG20 price.

Research hypothesis

H_{01}: There is no effect of lag volatility price of WIG20 index on today's price of WIG20

H_{02}: There is no effect of size, sign and persistence level on the volatility of WIG20 return.

H_{03}: There is no existence of short term and long-term components in WIG20 price.

Research methodology

Data Description

As per objective the study examines the effect of news and lag volatility on the stock price of Poland WIG20 by using daily data from 5th Jan. 1996 to 21st July 2026 with 7642 observations by applying different econometrics tools and techniques.

Tools & Techniques

During the study we have applied ADF/Unit Root Test for checking the stationarity in series, ARCH LM test used for heteroskedasticity and different GARCH family model like GARCH (1,1), Exogenous GARCH, TGARCH, Exponential GARCH and Component GARCH model applied to achieve objectives of the study.

Research methodology

We convert all data series into natural logarithm series by the formula

$$\mathbf{Ln\ (Pt\ /P\ t\text{-}1)*100}$$

Where Pt Closing price of the same day

Pt–1 Closing price of the previous day.

In this study, we have employed augmented Dickey Fuller (ADF) test of Dickey and Fuller (1979) and Phillips Perron test (PP) of Phillips and Perron (1988) to test stationarity of data series. We find all return series are stationary at level. There after we use GARCH family models to capture volatility effect as well as component effect. The specifications of models are as follows.

Augmented Dickey–Fuller Tests (ADF)

The Augmented Dickey-Fuller (ADF) test is an extension of the Dickey-Fuller test that is suitable for larger and more complex time series samples. While the simple Dickey-Fuller test is limited to AR (1) processes, the ADF test allows for capturing the presence of p lags in the model.

The general equation for ADF is applied in the series as follow:

$$\Delta yt = \alpha + \beta t + \gamma\ yt\text{-}1 + \delta 1\ \Delta yt\text{-}1 + \ldots\ldots + \delta p \Delta yt\text{-}p + et$$

Where α is a constant, β is the coefficient on a time trend and p is the lag order of the autoregressive process.

ARCH LM test

ARCH LM test for examine the existence of Volatility Clustering Financial time series data often demonstrate volatility clustering, meaning that volatility in the data tends to be auto correlated. This violates the assumption of constant variance for the error term in regression analysis. To address this issue, one approach is to use an ARCH (Autoregressive Conditional Heteroscedasticity) model, which not only models the mean but also models the conditional variance. In an ARCH model, the conditional variance is permitted to depend on the lagged values of squared error terms. This can be expressed in the following equation:

$$\mathbf{Var}\,(\epsilon_t|I_{t-1}) = \alpha_0+\sum^{p}_{i=1} \alpha_i\epsilon^2_{t-i}$$

Where $\epsilon_t$represents the error term at time t, I_{t-1}denotes the information set available up to time t-1, α_0 is the constant term, α_i (for i = 1 to p) represents the coefficients of the lagged squared error terms, and p is the lag length.

EXOGENOUS EGARCH (1,1)Model

The exogenous EGARCH (Exponential Generalized Autoregressive Conditional Heteroskedasticity) model is a variant of the popular EGARCH model that incorporates exogenous variables to capture additional information and improve the modelling of conditional volatility. In the exogenous EGARCH model, the conditional variance of a time series is modelled as a function of lagged conditional variances, exogenous variables, and the past shocks. The model allows for asymmetry in the volatility response to positive and negative shocks.

Mathematically, the exogenous EGARCH model can be represented as follows:

$$\mathbf{Log}(\sigma_t^{2})= \omega +\sum^{p}_{i=1} \alpha_i\,(|\,r_{t-i}| - \gamma_i\, r_{t-i}\,) + \sum^{q}_{j=1} \beta_j \log(\sigma^2_{t-j}\,) + \sum^{m}_{k=1} \delta_k x_{tk}$$

Where:

1.Σ_t^{2}represents the conditional variance at time t,

2.Ω is the intercept term,

3. P is the order of the absolute value shock term,

4.R t−i denotes the past shocks,

5.Γi captures the leverage effect, which measures the asymmetry in the response to positive and negative shocks,

6. Ai and βj are the model parameters,

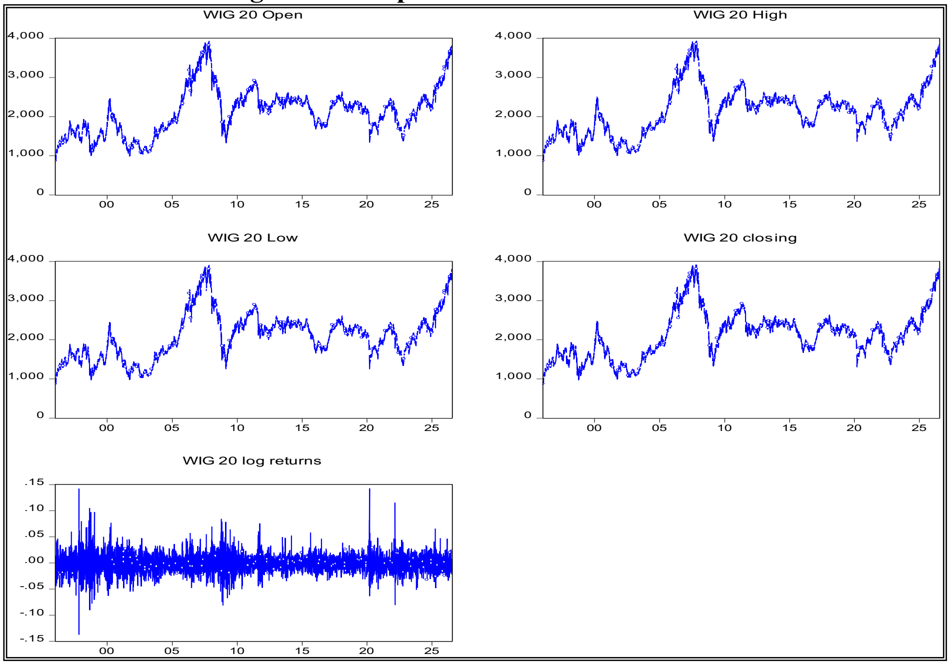
7. $\mathbf{Log}(\sigma^2_{t-j}\,)$ represents the logarithm of the conditional variance at time t−j,

8.Q is the order of lagged conditional variances, and

9.X_{tk} denotes the exogenous variables at time t and their corresponding coefficients δ_k

- **Graphical Presentation of the series:**

Figure 1 - Graphical Presentation of the series



Source: *Author's Own Calculation*

Descriptive Statistics:

Table 1 - Descriptive Statistics

	WIG_20_ OPEN	WIG_20_ HIGH	WIG_20_ LOW	WIG_20_ CLOSING	WIG_20_ LOG_RETURNS
Mean	2119.789	2136.224	2101.707	2119.346	-0.000194
Median	2161.360	2177.270	2142.965	2158.595	-0.000122
Std. Dev.	592.3897	596.2103	586.9608	591.8807	0.016043
Skewness	0.477708	0.480024	0.474132	0.477931	0.300313
Kurtosis	3.144499	3.154868	3.135968	3.144976	8.308236
Jarque-Bera	297.3055	301.1196	292.2083	297.6214	9085.823
Probability	0.000000	0.000000	0.000000	0.000000	0.000000
Observations	7642	7642	7642	7642	7641

Source: *Author's own Calculation*

The empirical evaluation encompasses 7642 Observations of the Poland top WIG 20 Index across various Training dimension Including opening price, closing prices and logarithmic returns the price series demonstrate consistent Central tendencies with mean and median values closely aligned average price level fluctuate between two 101.7 and 2136.224. Price indicators show robust standardisation Raising from approximately 586.96 To 596.21 Highlighting substantial absolute Price Dispersion within the market. Skew miss coefficient across all variable remaining positive ranging from 0.300313 to 0.480024 Indicating Slight rifled asymmetric Price metrics exhibits procure statistics near Thing where Wiz For the withdrawal reveals high leptokurtic peak of 8.308236.

Unit Root/Stationarity Test/ ADF Test

Table 2 - Unit Root/Stationarity Test/ ADF Test

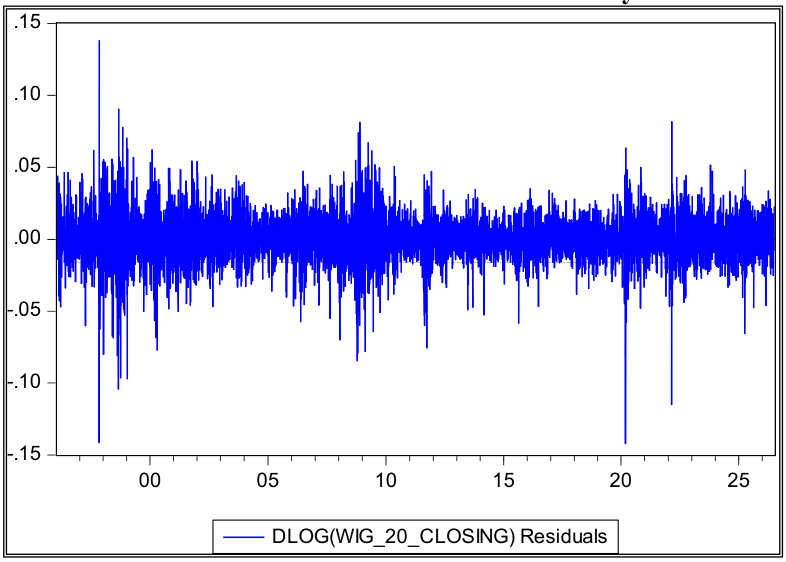
ADF and KPSS Unit Root Test for the Return series of Poland WIG20 Closing Price				
Model with Intercept as well as Trend & Intercept at level				
	ADF Test		**KPSS Test**	
	Data at level		**Data at level**	
Variable	**Intercept**	**Trend &Intercept**	**Intercept**	**Trend &Intercept**
WIG 20 lnclosing	-86.78315 (0.0001)	-86.77815 (0.0001)	0.077701	0.068494

Source: *Author's own Calculation*

Table 2 represents the result of ADF and KPSS test for checking the stationarity of the series. Here, the analysis used the return series for examine the unit root problem and result depicts that the transformed series is coming stationary at level in both KPSS and PP test. Generally, it was found that the data of stock exchange most probably comes non-stationary at level when we check it at original series. So, these series are behaving in the same line and it comes stationary at first difference when we check it at original series.

ARCH LM Test /Heteroskedasticity Test: ARCH for measuring the existence of Volatility Clustering

Table 3 - ARCH LM Test /Heteroskedasticity Test

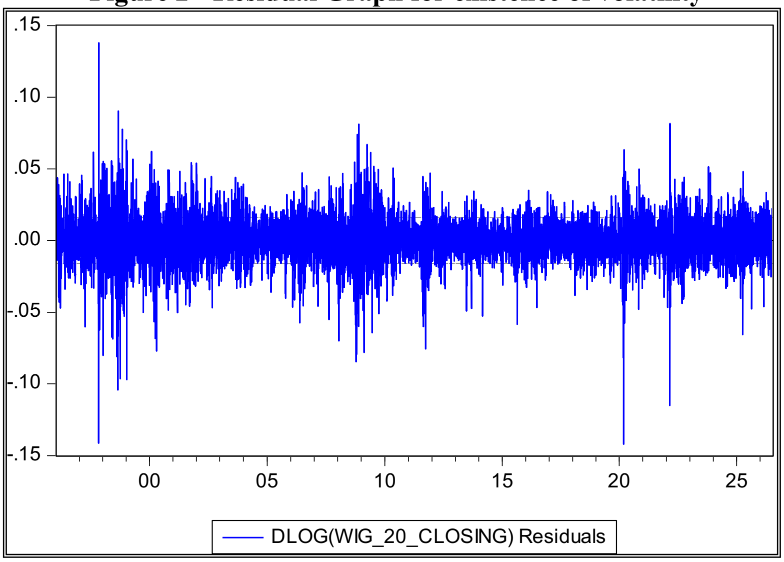


Source: *Author's own Calculation*

Table 3 display the result of Autoregressive conditional Heteroskedasticity Lagrange Multiplier Test performed to examine the existence of volatility clustering Within the model residuals. The probability value for both the F statistic and observed R-squared are strictly less 0.05, the Null Hypothesis of Homoskedasticity is rejected. This confirmed the presence of significant conditional Heteroskedasticity and robust Volatility cluster in the series Justifying the application of ARCH/GARCH Model frameworks.

Residual Graph for existence of volatility

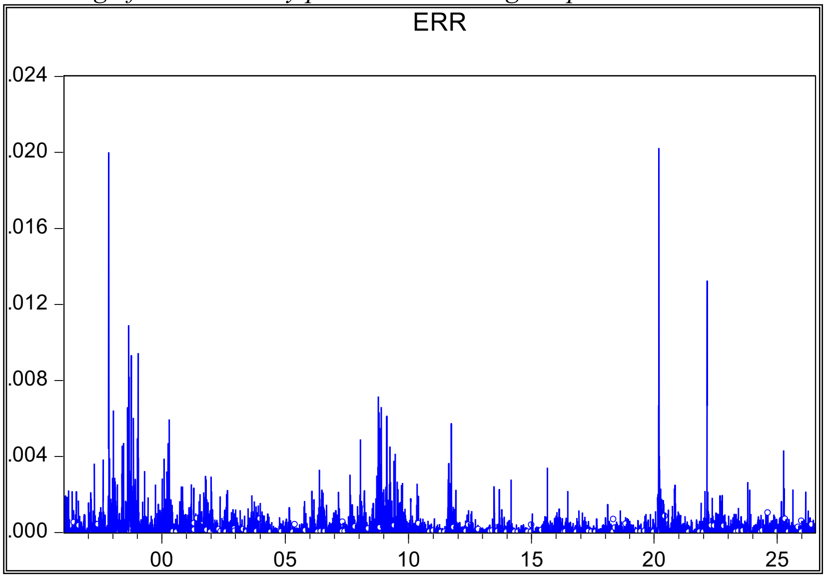
Figure 2 - Residual Graph for existence of volatility



Source: *Author's own Calculation*

Figure 3 depicts the significant volatility period exist during the period where Spikes represent heteroskedasticy rather than homoskedasticity.

Figure 3 - Significant volatility period exist during the period



Source: *Author's own Calculation*

Application of GARCH Family Models

GARCH (1,1) Model

GARCH = C(6) + C(7)*RESID(-1)^2 + C(8)*GARCH(-1)

Table 4 - GARCH (1,1) Model

Dependent Variable: DLOG(WIG_20_CLOSING)				
Mean Equation				
Variable	Coefficient	Std. Error	Z-Statistic	Prob.
C	0.000349	0.000268	1.302939	0.1926
AR(1)	-0.180190	0.874774	-0.205985	0.8368
AR(2)	0.254691	0.605195	0.420841	0.6739
MA(1)	0.196491	0.874186	0.224770	0.8222
MA(2)	-0.262003	0.613163	-0.427298	0.6692
Variance Equation				
C	**0.000107**	1.39E-05	7.697542	0.0000
RESID(-1)^2	**0.149850**	0.019532	7.671992	0.0000
GARCH(-1)	**0.599850**	0.044643	13.43674	0.0000

Source: *Author's own Calculation*

Table 4 depicts the intercept parameter © captures the baseline or unconditional long term variance level within the conditional volatility framework and RESID(-1)^2 shows the coefficient for the lagged squared residual term quantifies the immediate transmission of market shocks or recent news (**0.149850**) innovations onto current conditional volatility. GARCH(-1) reflects the degree of persistence (**0.599850)**, measuring how preceding condition volatility forecasts influence the present days predicted variance. So combined parameter magnitude remains below one indicating mean reverting behaviour and decaying volatility dynamics where current market variance diminishes relative to prior periods.

Exogenous GARCH Model:

GARCH = C(4) + C(5)*RESID(-1)^2 + C(6)*GARCH(-1) + C(7)*DLOG(WIG_20_OPEN(-1)) + C(8)*DLOG(WIG_20_HIGH(-1)) + C(9)*DLOG(WIG_20_LOW(-1))

Table 5 - Exogenous GARCH Model

Mean Equation				
Variable	Coefficient	Std. Error	Z-Statistic	Prob.
C	0.000198	0.000154	1.291702	0.1965
AR(1)	-0.573714	0.194784	-2.945382	0.0032
MA(1)	0.595800	0.191026	3.118955	0.0018
Variance Equation				
C	**2.91E-06**	3.65E-07	7.957517	0.0000
RESID(-1)^2	**0.060208**	0.003393	17.74480	0.0000
GARCH(-1)	**0.928553**	0.003983	233.1203	0.0000
DLOG(WIG_20_OPEN(-1))	**0.001337**	0.000412	3.244643	0.0012
DLOG(WIG_20_HIGH(-1))	0.000288	0.000435	0.661017	0.5086
DLOG(WIG_20_LOW(-1))	**-0.002184**	0.000480	-4.545306	0.0000

Source: *Author's own Calculation*

Table 5 presents the estimation results of the Exogenous GARCH model, integrating both conditional mean dynamics and conditional variance properties augmented with exogenous market covariates derived from the WIG20 index series. In the mean equation, the autoregressive parameter AR(1) coefficient of -0.573714 (p=0.0032) and MA (1) coefficient of 0.595800 (p=0.0018) both are statistically significant, indicating robust short term serial dependency and adjustment mechanism in the conditional mean return. In the variance equation the lagged residual term (RESID(-1)^2) exhibits a significant Coefficient of 0.060208 reflecting the immediate transmission of market shocks. Furthermore, the lagged conditional variance depicts high and statistically significant coefficient of 0.928553, demonstrating extreme volatility persistence in the market. In the exogenous variable Incorporating Neg Now return of the WIG 20 index dimensions show mixed significant effect on conditional volatility. Specially, DLOG(WIG_20_OPEN(-1)) display positive and significant effect of (**0.001337 , p= 0.0012**), whereas DLOG(WIG_20_LOW(-1)) reveals a significant inverse relationship between todays return and previous day high return.(**-0.002184, p=0.0000).** Conversely, the high price exogenous regressor **(**DLOG(WIG_20_HIGH(-1)) remains Statistically insignificant (0.5086).

Exponential GARCH Model:

LOG(GARCH) = C(4) + C(5)*ABS(RESID(-1)/@SQRT(GARCH(-1))) + C(6)*RESID(-1)/@SQRT(GARCH(-1)) + C(7)*LOG(GARCH(-1))

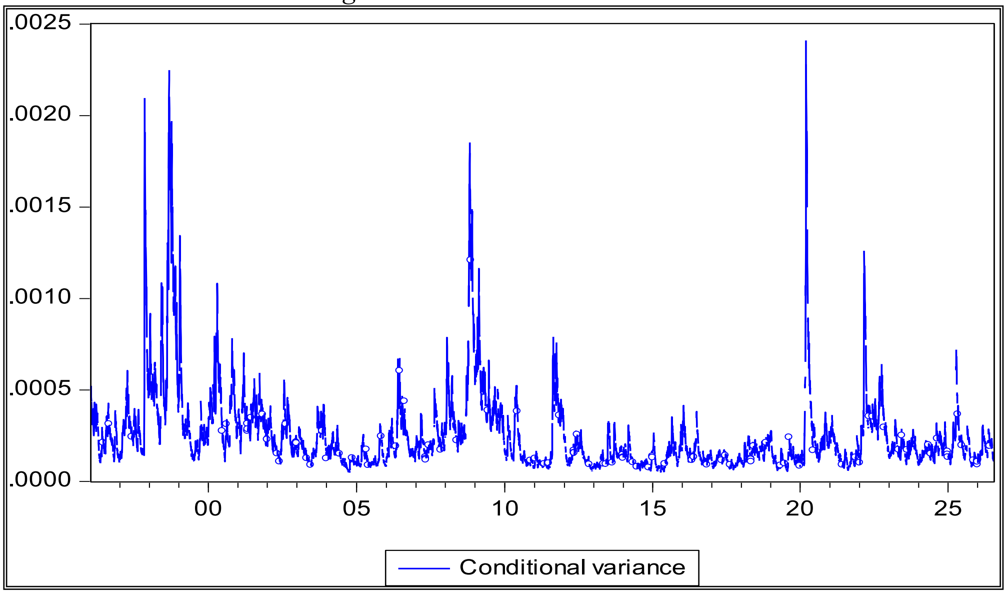
Table 6 - Exponential GARCH Model

Dependent Variable: DLOG(WIG_20_CLOSING)				
Sample (adjusted): 1/09/1996 7/21/2026				
Included observations: 7640 after adjustments				
Mean Equation				
Variable	**Coefficient**	**Std. Error**	**Z-Statistic**	**Prob.**
C	0.000175	0.000153	1.147123	0.2513
AR(1)	-0.279911	0.398080	-0.703153	0.4820
MA(1)	0.305510	0.394916	0.773607	0.4392
Variance Equation				
C(4)	-0.247094	0.018036	-13.69983	0.0000
C(5)	**0.146944**	0.006445	22.79954	0.0000
C(6)	**-0.048942**	0.004261	-11.48665	0.0000
C(7)	**0.984203**	0.001878	524.1416	0.0000

Source: *Author's own Calculation*

Table 6 represents the estimation outcomes for the exponential GARCH Model applied to the WIG 20 closing log return across 7640 adjusted observations. Asymmetric volatility and shock magnitude C (5) and C6; In the various equation the coefficient C(5) is estimated at 0.146944 (P - 0.0000), capturing the magnitude effect or the overall impact of shock on volatility. Meanwhile, the asymmetric parameter C(6) is negative (-0.048942) and statistically Significant (p-0.0000), confirming the presence of Asymmetric Leverage effect Where negative markets shocks (bad news) are induce higher volatility than positive shock of an equivalent Scale. The persistence coefficient C(7) associated with {GARCH}(-1)) is Significant at 0.984209 (p–0.0000), demonstrating extreme persistence of shock and long memory in the conditional variance of the market Index.

Figure 4 - Conditional Variance



Source: *Author's own Calculation*

Table 7 - CGARCH Model

Dependent Variable: DLOG(WIG_20_CLOSING)				
Sample (adjusted): 1/09/1996 7/21/2026				
Mean Equation				
Variable	**Coefficient**	**Std. Error**	**Z-Statistic**	**Prob.**
C	0.000375	0.000144	2.598253	0.0094
AR(1)	0.315088	0.225535	1.397070	0.1624
MA(1)	-0.314415	0.225392	-1.394968	0.1630
Variance Equation				
C(4)	**0.000236**	5.34E-05	4.414699	0.0000
C(5)	**0.996810**	0.001563	637.6894	0.0000
C(6)	**0.022798**	0.008233	2.768965	0.0056
C(7)	**0.045502**	0.009082	5.010049	0.0000
C(8)	**0.918777**	0.014779	62.16641	0.0000

Source: *Author's Own Calculation*

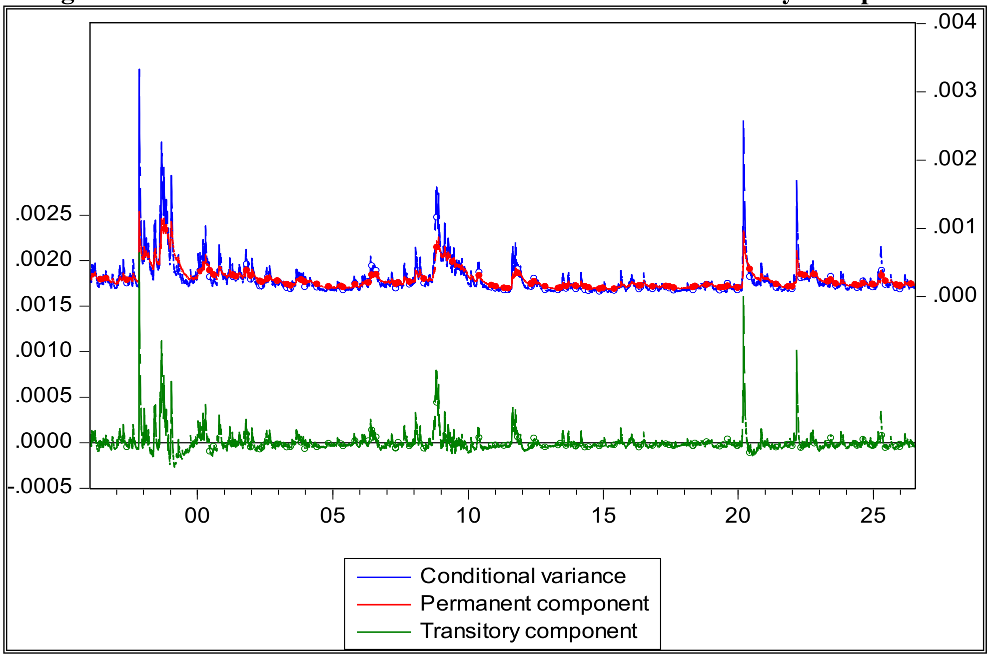
Component (CGARCH) Model

Model : Q = C(4) + C(5)*(Q(-1) - C(4)) + C(6)*(RESID(-1)^2 - GARCH(-1))
GARCH = Q + C(7) * (RESID(-1)^2 - Q(-1)) + C(8)*(GARCH(-1) - Q(-1))

Table 7 depicts the estimation output for the component GARCH model applied to WIG20 closing log return across the adjusted sample period. Permanent component dynamics C4 and C-5; In the variance equation, the Permanent component Intercept C(4) is positive and significant at 0.000236 (P - 0.0000) Furthermore, the persistence parameter after permanent volatility component C-5 is highly significant at 0.99681 (p-0.0000), indicating an extremely high degree of longevity and slow mean reversion for the trend component of variance.

Permanent component and shock parameter (C(6) C(7) C(8)); The transitory volatility dynamics are captured by parameters C(6) C(7) C(8), Which are Statistically Significant at 1% level (p-0.0000 to 0.0056) . Specially, the innovation term C (6) is 0.022798 While C7() and C(8) are recorded at 0.045502 and 0.918777 respectively, Validating the decomposition of conditional variance into permanent and transitory component.

Figure 5 - Conditional Variance and Permanent and Transitory Components



Source: *Author's own Calculation*

Conclusion and discussion of empirical findings

The empirical evaluation of the Poland stock market demonstrates that log return exhibit near zero means with high positive Kurtosis (8.308). For volatility clustering and heteroskedasticity ARCH-LM test diagnosed and confirms the presence of robust conditional heteroskedasticity and volatility clustering, Evidence by highly significant F-statistics (259.745) and Obs. R-square values (915.086) at the 1% level. Baseline and GARCH-X model confirm extreme shock persistence and mean -reverting decay properties, where exogenous variables such as opening price and low price exert statistically significant distinct impacts on market variance.

Advanced modeling via the EGARCH models framework establishes a significant leverage effect (C(6)=-0.0489), proving that negative shocks generate higher volatility than positive innovations. Furthermore, the component GARCH model successfully separates variance into a highly persistent permanent trend (C(5)=0.9968) and a transitory component offering critical insights into the risk structure and shock transmission mechanisms within the Poland's financial market.

Authors' Contributions:

The authors contributed equally to this work.

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